

Introduction

The receiver for the remote control vehicle project must have a suitable integral AGC system for satisfactory operation. Multipath, deep fades, as well as potential changes in signal strength due to distance from the operator must be accounted for. Although no calculations have been performed to date, it is anticipated that an AGC range of at least 60 dB, if not approaching 80 dB will be required. The design discussed here starts out simplistically looking at only one stage of AGC, gradually building up to the final proposed design for this application. The actual design details for the AGC as implemented are presented at the end of this short memo.

Single AGC's Stage Design

The illustration in Figure 1 is that of a single stage AGC amplifier applied from a single integrator AGC system. Two things must be looked at in the design of this AGC stage. A review of the available gain in the main channel (50 MHz) must be performed, followed by a review of the actual frequency domain stability of the AGC system (DC – kHz). If the forward gain of the IF amplifier is insufficient (at 50 MHz), no amount of AGC loop

performance will allow the loop to close and maintain a designated output signal level. This is the first design detail undertaken here.

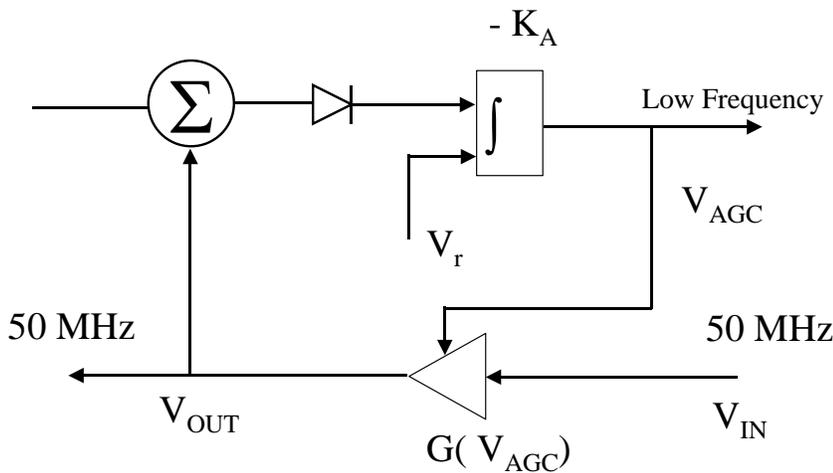


Figure 1

Simplified AGC System Using Single-Stage Amplification

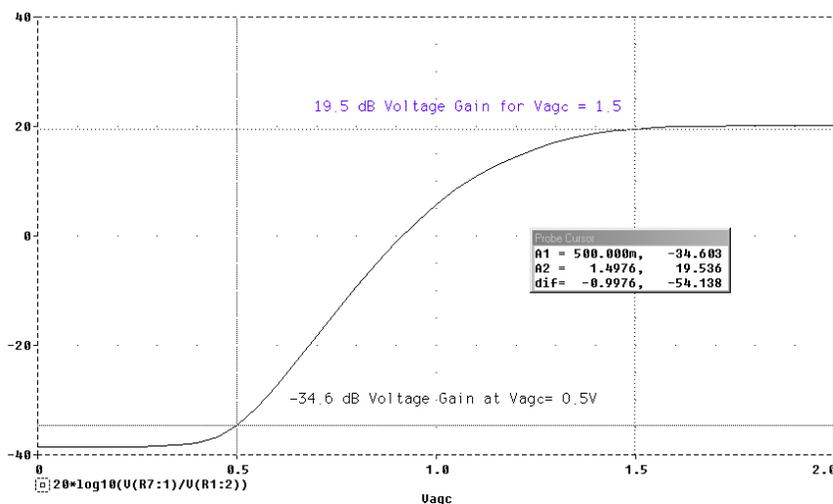
performance will allow the loop to close and maintain a designated output signal level. This is the first design detail undertaken here.

The amplifier in this first example is a CLC520 variable gain amplifier. Its characteristics extend from a voltage gain of -80 dB to as high as +20 dB. Obviously, to recover micro-volt signal levels considerably more gain will be required beyond +20 dB. More on that later.

The gain characteristics v.s. V_{AGC} voltage are shown in Figure 2 and 3. Figure 2 is Spice-derived while Figure 3 provides actual fit-data using the “polyval” function within MatLab.

This is a nonlinear characteristic and a fifth-order polynomial was used to fit the data. The data used was a combination of application note data (below a V_{AGC} of 0.4 V) and that simulated using PSPICE and the Comlinear Spice model. The available gain in Figure 2 is as mentioned in the paragraph above, 20 dB. It is very important to choose the proper polynomial order and fit the data extremes sufficient to safeguard the root solver which is used to solve the nonlinear equation which results.

Figure 2
Single CLC520 With
Manual Gain Control



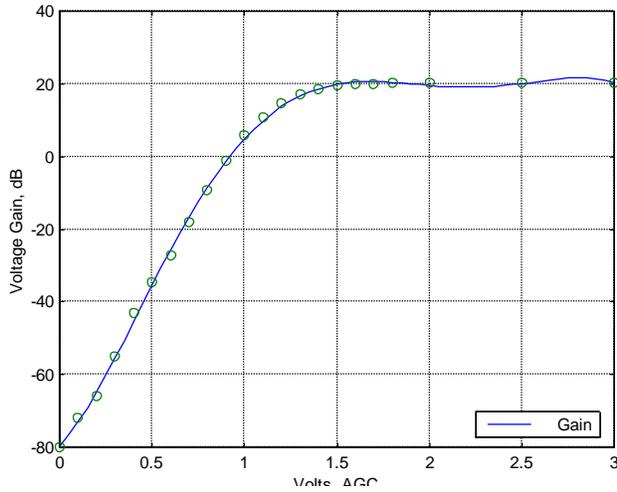


Figure 3
Amplifier Gain Characteristic v.s. AGC Voltage

Figure 4 illustrates the CLC520 gain as a function of input power level. The AGC loop was set with a reference voltage which developed this power output level. In actuality much of this signal gain would be performed at baseband signal level rather than IF or RF.

To the left is Figure 3 showing the fitted performance using polynomial fitting. As will be seen in the full-up development, polynomial fitting can provide inadequate accuracy at critical points, thus requiring use of a spline routine for data interpolation.

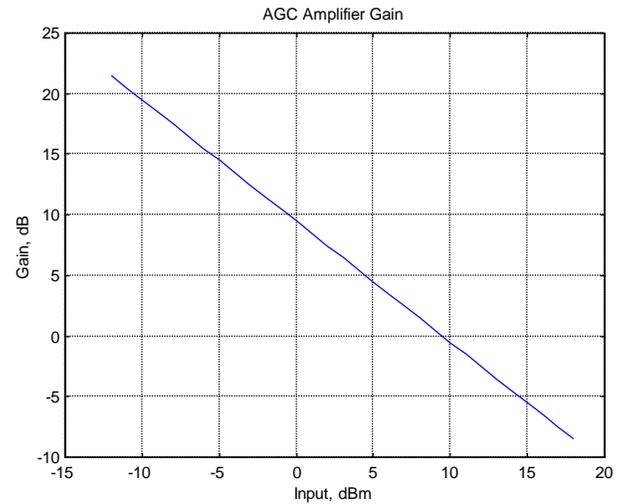


Figure 4
IF Amplifier (CLC520) Gain v.s. Input Power for a Constant ~ 10 dBm Output Level

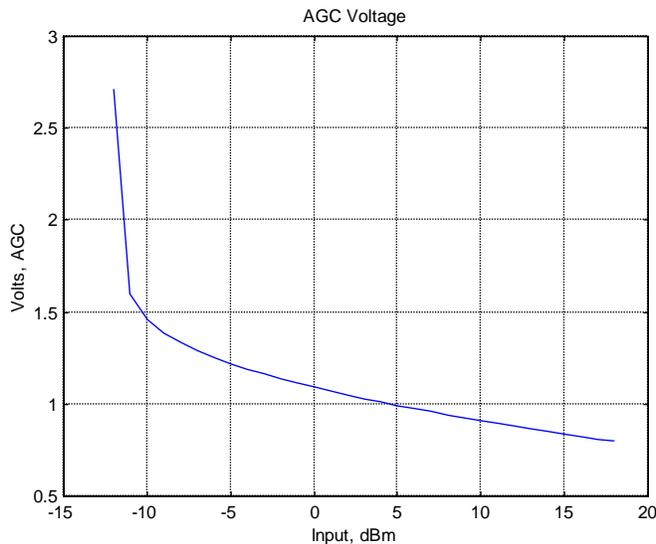
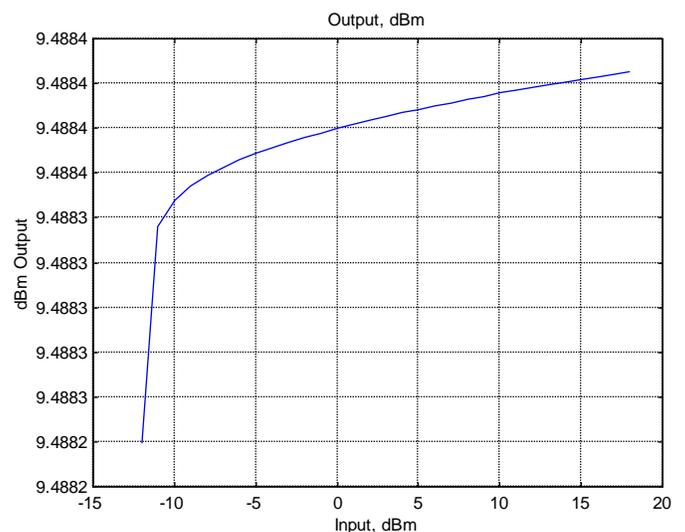


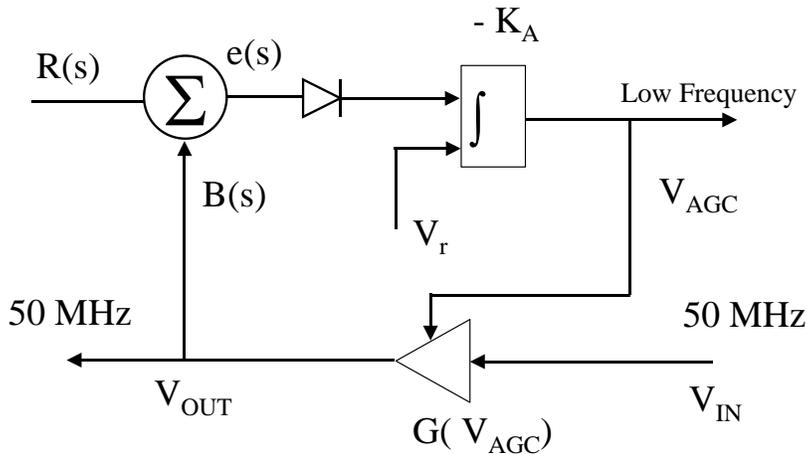
Figure 5
IF Amplifier (CLC520) AGC Voltage v.s. Input Power for a Constant ~ 10 dBm Output Level

To the left in Figure 5 is the AGC voltage developed in the feedback loop which is applied to the AGC port of the CLC520. As is seen at an input level of ~ -11 dBm, the gain of the amplifier is becoming insufficient to fully develop the output power requested of the system, i.e. ~ 10 dBm. At this point the AGC voltage becomes increasingly positive, asking for more and more IF amplifier gain.

Figure 6
IF Amplifier (CLC520) Output Level v.s. Input Power for a Constant ~ 10 dBm Output Level Request



Equation Development for Single-Stage AGC System



The closed-loop equation for the system illustrated at the left is as follows.

$$V_{agc} = -K_a (e(s) K_D + V_r)$$

$$e(s) = R(s) + V_{in} G(V_{agc})$$

Substituting:

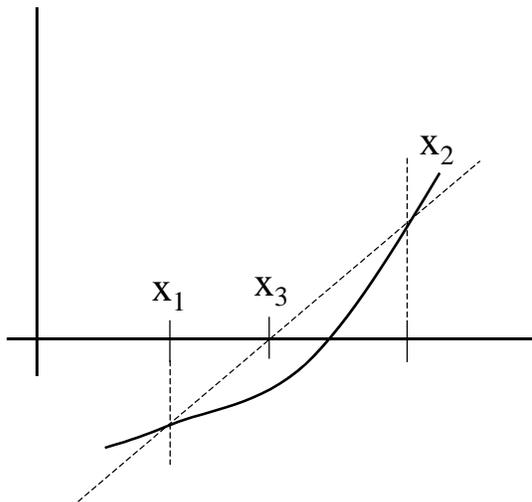
$$K_a \{ R(s) + V_{in} G(V_{agc}) \} K_D + V_r = 0$$

$G(V_{agc})$ is the polynomial-fit data from the data sheet (Figure 3) and $R(s)$ is identically zero in the normal case. It is used if one is interested in a transient response to a step or ramp input. K_D is the diode detection coefficient and V_r is the offset voltage chosen which causes the proper output signal level to be developed at the output of the AGC amplifier. The MatLab routine solves this equation over the requested input signal range and converges to a solution if one exists. In cases where the input signal level is so low as to not allow sufficient output power from the AGC amplifier, no solution exists.

The solution technique is extremely simple, but is effective in some of the nonlinear circumstances which can develop.

Recursively search between -3 V AGC and 0 V AGC for a cross over situation where the equation above gives a sign reversal. In other words $f(x_1) \times f(x_1 + \Delta x) < 0$.

Exit incremental search routine and utilize similar triangles to locate root of the transcendental equation.



$$\frac{-y_1}{x_3 - x_1} = \frac{y_2}{x_2 - x_3}$$

$$x_3 = \frac{x_2 y_1 - x_1 y_2}{y_1 - y_2}$$

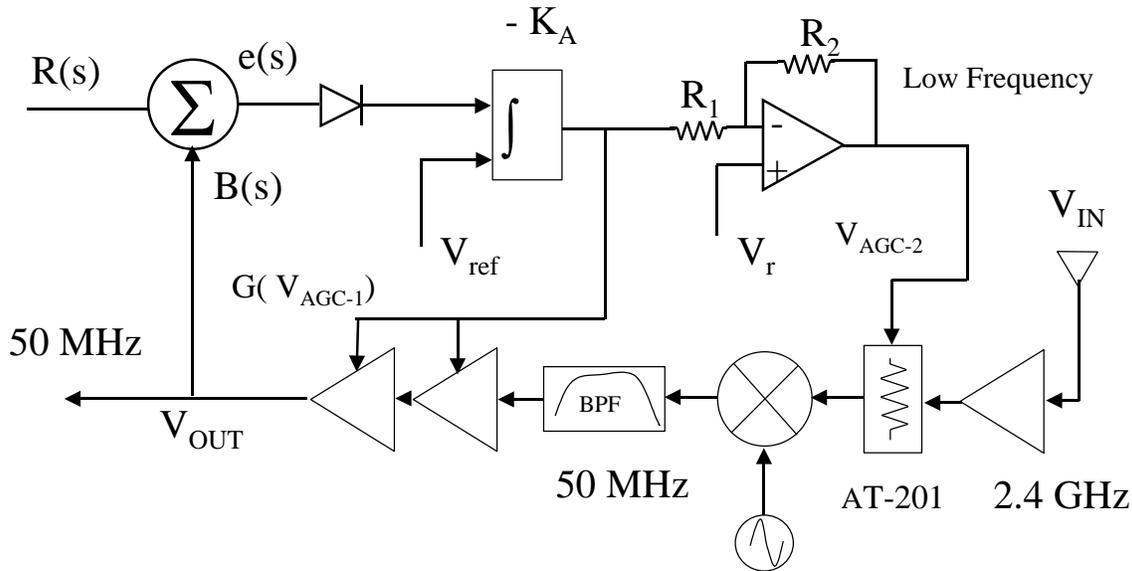
Equation Development for Two-Stage AGC System

The two-stage AGC system is very similar to the single stage, but with some added complexities. A high level of gain is required for proper operation at low signal levels so a new device, the RF MicroDevices RF2604 IF amplifier was chosen as the AGC amplifier. It offers on the order of $> +90$ dB of gain if all four internal stages are used. Of primary concern is the high potential for internal oscillations due to this abundance of gain at a single frequency,

therefore, in the actual design this single AGC amplifier will be divided into two identical RF2604s with the AGC voltage applied to both. The analysis of this scenario is precluded at this time due to lack of data available describing the RF2604 in this reduced configuration; actual breadboarding will have to supply this information.

Coupled with the RF2604 AGC amplifiers is a Ma-Com voltage adjustable attenuator which is placed just after the front-end LNA. The AT-201 has adjustable attenuation from 1.3 dB (minimum insertion loss) to approximately > 30 dB. Use of this attenuator safeguards the front-end mixer from overly strong input signal levels and provides an improved distribution of gain in the channel. The onset of attenuation in the AT-201 must be delayed relative to decreased gain at the IF in order to prevent preliminary degradation to system noise figure and the accompanying decreased channel signal-to-noise ratio.

The proposed multiple AGC system is shown below. V_{ref} sets the actual power level at the output of the second IF AGC amplifier. It is thought most optimum to have this level around -10 to -15 dBm. This level is most convenient for any subsequent mixer down-conversion. In our application the video signals will be upconverted to channels 3 and 4, with the -10 to -15 dBm signal level being optimum. For the digital channels more gain will be



required perhaps in order to properly drive the BPSK demodulators. This design attribute has not been looked at specifically by me. V_r is a calculated value which properly scales the V_{AGC-1} voltage to the suitable range (V_{AGC-2}) for the Ma-Com AT-201.

The actual detector sensitivity, K_D , is a function of both a) voltage delivered to its attached load and b) the amount of power absorbed in the diode. Since we are “tapping off” some small amount of signal power and terminating the diode in the input impedance (hi-Z) of an operational amplifier, it is not a trivial matter to calculate this particular value. In practice one cannot have *enough stable* gain at DC and the amount of gain available is directly related to the amount of steady-state error remaining in the loop. The best way to plan for the variability in K_D is to make every attempt to safeguard the DC gain of the integrator. The actual component curves used in the MatLab simulation accompany this report subsequently.

Calculation of the R_1 , R_2 , and V_r Values

A mapping of AGC voltage V_{AGC-1} to V_{AGC-2} must be performed. The AGC amplifiers utilize a different voltage range for their function than does the AT-201 voltage variable attenuator.

AGC Amplifier – RF2604		Ma-Com AT-201 Attenuator	
Gain	AGC-1 Voltage	Gain	AGC-2 Voltage
+ 80 dB	+ 2 V	-1.3 dB	-3.0 V
+ 10 dB	0 V	~ -30 dB	-2.0 V

Using the figure above as a reference, the loop equation for the level shifting op-amp circuit is the following:

$$-V_i \frac{R_2}{R_1} + V_r \left(1 + \frac{R_2}{R_1} \right) = V_{out}$$

Using the desired voltage conditions in the table above and solving two simultaneous equations gives the required resistor ratio and the voltage V_r required for the scale and level change. Two example values are given in the table immediately below.

In order to obtain a “delayed” AGC action it may be desirable (in this case it is) to change the scaling somewhat such that the attenuator is driven more than 3 volts negative. This results in the attenuator increasing its loss characteristics at higher signal levels, thus degrading system noise figure only after the sufficient signal-to-noise ratio has been established. In other words, the onset of attenuation in the AT-201 is delayed until the signal strength at the input becomes considerable.

Loss, dB	AGC, Volts	Relationships
1.3 dB	-3	$R_2 / R_1 = 3/4$
30 dB	-2	$V_r = -1.1429$ V
1.3 dB	-3.25	$R_2 / R_1 = 5/8$
30 dB	-2	$V_r = -1.231$ V

Solution of Voltage/Gain Relationships and Accompanying Component Values

Solution of Loop Equations

The equations solved in the simple algorithm do so with the independent variable being the AGC voltage, V_{AGC-2} . After the solution is obtained, this value is used to derive the accompanying value for V_{AGC-1} .

The equations utilized in the “solve” block with the incremental search followed by a similar triangle algorithm for interpolation are the following:

$$V_{AGC-2} = V_o \quad V_o \text{ is the current iterated “guess in the algorithm”}$$

$$V_{AGC-1} = \frac{R_1}{R_2} \left(-V_{AGC-2} + V_r \left(1 + \frac{R_2}{R_1} \right) \right)$$

$$ed = V_{in} \times 10^{(G_{LNA}/20)} \times 10^{(VV_Attn(V_{AGC-2})/20)} \times 10^{(G_{mixer}/20)} \times 10^{(polyval(co_1, V_{AGC-1})/20)}$$

$$Eq = \left(ed K_D - V_{ref} \right) K_a \frac{R_2}{R_1} + V_r \left(1 + \frac{R_2}{R_1} \right) - V_{AGC-2}$$

$VV_Attn()$ is a function which uses manufacturer’s data to perform a spline curve fit and return the interpolated attenuation value for the as-applied V_{AGC-2} voltage.

K_a is the open-loop gain of the operational amplifier used in the feedback loop.

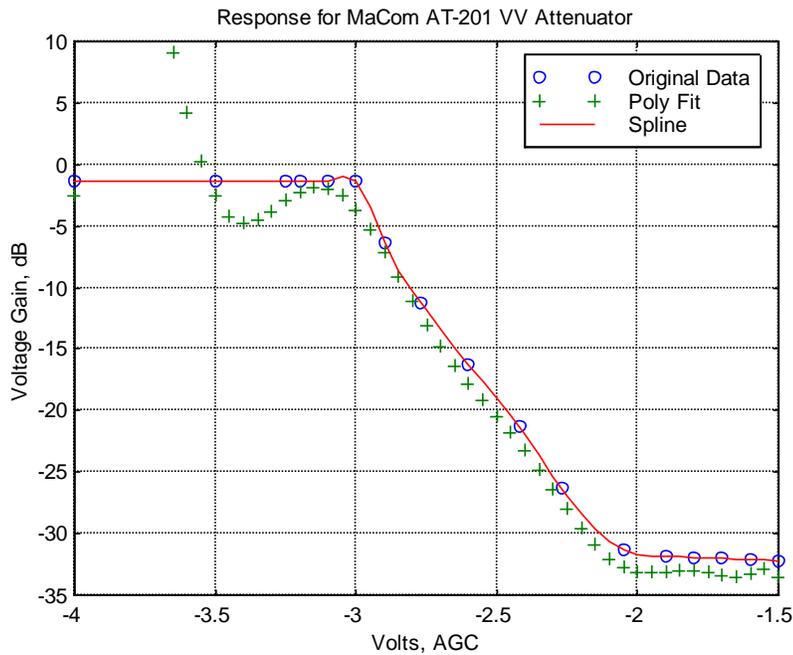
Upon finding the solution to the equations above, the following set of equations are used to calculate the gain of the associated AGC amplifiers and front-end attenuator, as well as the anticipated power output at the IF of 50 MHz.

$$V_{AGC-1} = \left(-V_{AGC-2} + V_r \left(1 + \frac{R_2}{R_1} \right) \right) \frac{R_1}{R_2}$$
$$Gain_1 = polyval \left(co_1, \left(-V_{AGC-2} + V_r \left(1 + \frac{R_2}{R_1} \right) \right) \frac{R_1}{R_2} \right)$$
$$Gain_2 = VV_Attn(V_{AGC-2})$$
$$dBm_Out = dBm_In + G_{mixer} + Gain_1 + Gain_2 + G_{LNA}$$

Some additional information on the curve fitting employed followed by one example calculation is found on subsequent pages. I have not rewritten this latter part of the report to integrate it seamlessly with the previous pages.

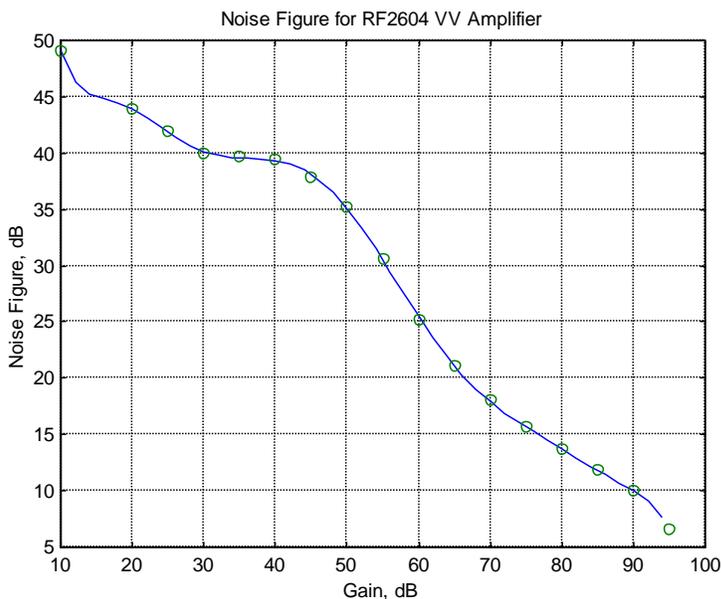
Multiple-Fed AGC System

A two-stage AGC system is now considered in which a front-end attenuator is gradually inserted after sufficient signal-to-noise is developed in the system. In this way the accompanying degradation in system noise figure will not deleteriously impact the received SNR. Other more exotic techniques¹ for AGC may be considered, offering greater immunity to deep fades, for example, but will not be considered at this point in time.



The figure to the left illustrates the loss characteristics of the voltage variable attenuator planned for use in the receiver. It is a MaCom AT-201 device. Any attempt to satisfactorily fit the manufacturer's data with a polynomial was unsuccessful so a spline routine was used in the simulation. This adds considerable "numeric noise" to the solutions available but not to the extent, it is believed, as to be deleterious to the overall assessment of the AGC system.

The spline-fit attenuator data is the solid line while the "+" points are what was best available through various order polynomial fits.



The curve to the left is a polynomial fit to the noise figure v.s. gain for the MicroDevices RF2604. The noise figure data was for a V_{CC} of +5 V, however, the gain data used in the simulation was for a V_{CC} of +3 V. The former gain characteristic had unfavorable humps in the gain v.s. AGC voltage and the only noise figure information available was for the V_{CC} of 5 V. Ideally the noise figure data could be measured for the V_{CC} of +3 V and used in a subsequent simulation effort.

This noise figure data is for the RF2604 utilizing all four internal stages of gain. It is felt that this is risky from the standpoint of so much

gain in one chip. Therefore, it is recommended that only three stages of gain be used and the noise figure / gain measured as a function of AGC voltage when operated from V_{CC} of +3 V.

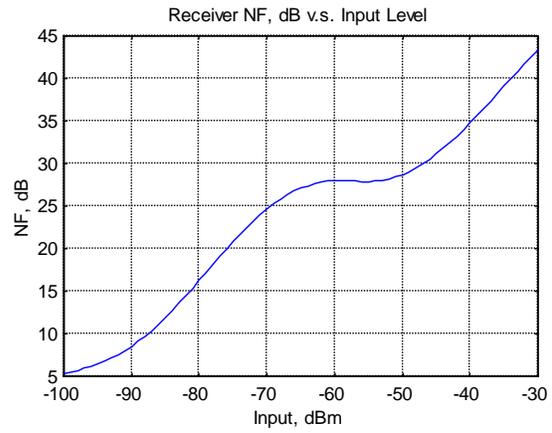
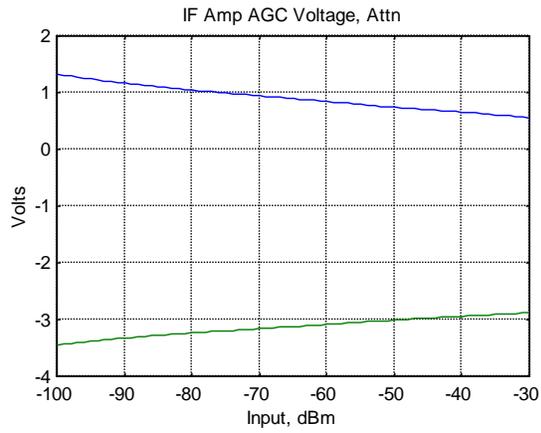
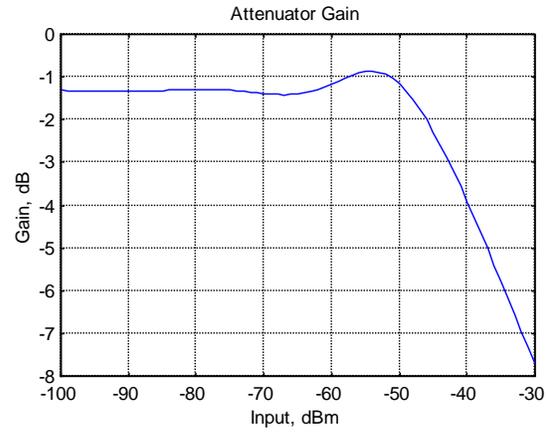
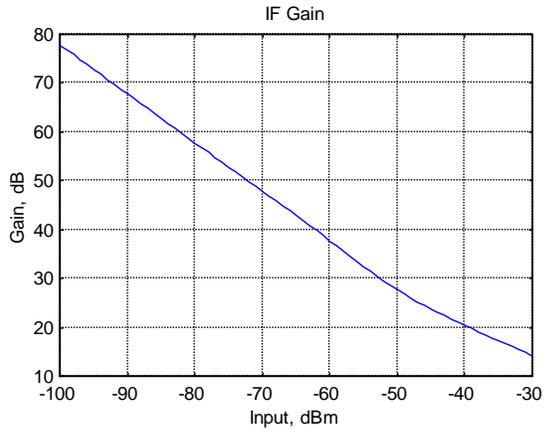
The set of graphs on the following page illustrate the overall simulated receiver performance. As is seen, the front-end attenuator is only increased after an input signal level of approximately -55 dBm. An internally adjustable

AGC Amplifier Design

by Jeff Crawford

July 24, 1999

voltage reference can be used to optimize the cut-in point for the front end attenuator. This will simultaneously optimize the noise figure available at low signal levels while mitigating development of spurious signals due to overdrive of the front-end mixer.

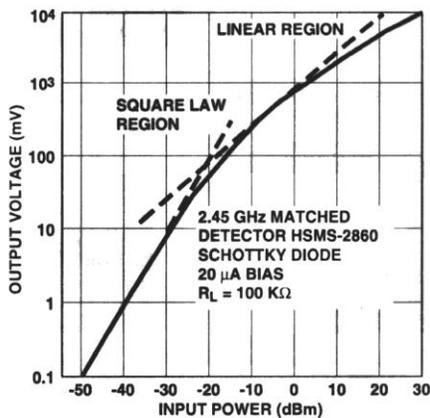


Appendix

One of the parameters used in the calculations entertained is the detector gain constant, K_D . In the literature² a factor of 0.15 is seen routinely, yet in other materials describing microwave detectors^{3,4} considerably lower detector constants are advocated. Where does this come from?

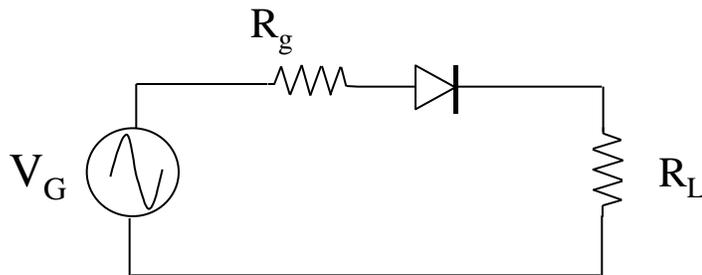
The first element highly influential in determining the actual value of K_D is the power level to which the detection diode is exposed. As seen in the figure below, if the input level is approximately -20 dBm or lower the detector acts as a square-law detector whose output is an indicator of signal power. If the input level is higher, however, the diode operates in its linear region and is proportional to the output voltage rather than power. The slope of the two curves, indicative of detection sensitivity, is different by a factor of two. In this application we will endeavor to stay in the square-law region, thus requiring the input to the detection diode to remain below approximately -20 dBm.

In the AGC application the pick-off point for the AGC feedback is just that, a pick-off point. Therefore, since the diode feeds the input of an operational amplifier whose input impedance is large, a slight modification must be made in our thinking. The true "load" on the output of the IF amplifiers is the 50Ω of the following stage, therefore the maximum voltage that may occur at the input to the detector/op-amp circuit is precisely



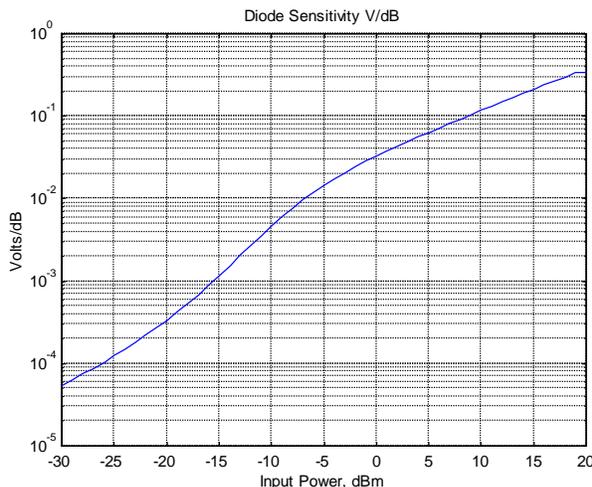
$$V_{peak} = \sqrt{2 \times 10^{P/10} \times 0.05}$$

The actual detection sensitivity to use for K_D thus becomes a little muddled.



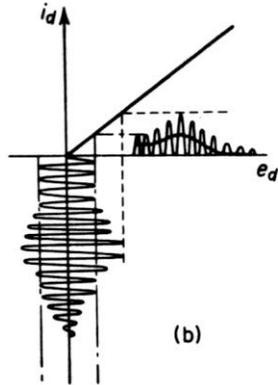
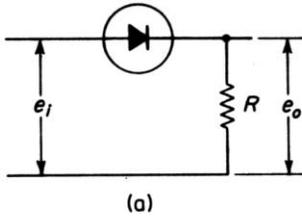
In the most simple form, the equation which must be solved to determine the detection sensitivity can be derived from the simplified schematic to the right. A number of factors are missing which, in reality, are present and will modify the results described here. To name only a few, spreading resistance, junction and other stray capacitance, and dynamic resistance will all impact the actual operation of the detector. The transcendental equation which must be solved is

$$-V_G + (R_G + R_L) I_s \left(e^{\frac{qV_D}{n k T}} - 1 \right) + V_D = 0$$



This equation can be solved through a combination of an incremental search followed by the secant method. If the input voltage is derived from integer-values in dBm, the actual detector sensitivity is easily evaluated in terms of V/dB. The figure to the left illustrates the outcome of this calculation for the following conditions: $I_s = 10^{-7}$ A, $R_G = 50$, $R_L = 100k\Omega$, $n = 1.2$, $T = 290$. At our anticipated signal levels the factor K_D may be as low as 5 mV/dB to 10 mV/dB, significantly less than 0.15 V/dB. The designer must take this into

account and ensure that the op-amp integrator has sufficient gain considering the level of K_D .



An upper limit on the K_D factor can be determined when in the linear region by looking at the following development⁵. In the figure to the left the diode is seen to rectify the composite RF/modulation. The average diode current is easily calculated using the following expression.

$$I_{avg} = \frac{1}{2\pi} \int_0^\pi \frac{E_{cm} (1 + m_a \cos(\omega_m t)) \cos(\omega_c t) d(\omega_c t)}{r_d + R}$$

r_d is the diode internal resistance and R the load. The solution for I_{avg} is

$$I_{avg} = \frac{E_{cm}}{\pi(r_d + R)} + \frac{m_a E_{cm} \cos(\omega_m t)}{\pi(r_d + R)}$$

We see that the linear detection process results in two components, the first a direct current component and the second a current that changes proportionately with the original modulation. For the AGC circuit the control bandwidth is much smaller than the modulation bandwidth so the only element which applies is the DC component. At best the conversion efficiency is approximately 30% due to the factor of π in the denominator alone.

In higher frequency applications than the AGC design, other frequency-dependent characteristics must be considered as they strongly impact the actual detection performance. The current sensitivity⁶ of a detector is defined as

$$\beta_i = \frac{i_{dc}}{P_a}$$

where P_a is the input power absorbed by the diode
 i_{dc} is the DC output current

$$\beta_i = \frac{q}{2\eta k T} \frac{1}{(1 + R_s/R_j)^2} \frac{1}{1 + \omega^2 C_j^2 R_s R_j / (R_s + R_j)}$$

In many instances throughout the literature, especially in manufacturer's application notes, β_i is in units of $\mu A/\mu W$ or similar. These units are very disadvantageous for the AGC application as the characteristics of the AGC amplifier are usually in terms of dB/V with the optimal units for the detector being the inverse, V/dB. The detector open-circuit voltage sensitivity can be defined as the voltage drop across the junction resistance when the diode is open-circuited

$$\beta'_v = \beta_i R_j$$

where R_j is the diode junction resistance

Single-Stage AGC as First Illustrated

Filename: agc.m

```
% Analysis of Single-Stage AGC Amplifier
% Jeff Crawford
% July 24, 1999
%
%Obtain most suitable coefficients to describe amplifier data
%
co2=0;
coef = AGC_Amp;
%
format long e
dBm_low = -12;    dBm_hi = 18;    R = 50;
Ka=1e6;
Kc=1.0;
Vr= -0.10;
Kd=0.15;
max_itr=500;
itr=0;
cst = [Ka,Kc,Vr,Kd];
Vagc = 0;
Gain = 0;
dBm_Out = 0;
%
%format short;
% Input power level for AGC amplifier
m = dBm_low:1:dBm_hi;
V = sqrt(10.^(m*0.1)*0.001*R);
if length(Vagc)> 0
    clear Vagc
end
if length(Gain)> 0
    clear Gain
end
if length(dBm_Out)> 0
    clear dBm_Out
end
for k = 1:length(m)
    dBm_In(k) = dBm_low + k - 1;
    V_trial = 0.1;
    while V_trial < 2.5
        x1 = theEq(V(k),V_trial,coef,cst);
        x2 = theEq(V(k),V_trial+0.05,coef,cst);
        if x1*x2 < 0
            break
        end
        V_trial = V_trial + 0.05;
    end
    % end WHILE
    x1 = V_trial;
    x2 = V_trial + 0.05;
    error = 1e6;
    y1 = theEq(V(k),x1,coef,cst);
    y2 = theEq(V(k),x2,coef,cst);
    itr=0;
```

```
while error > 0.00001
    x3 = (x2*y1 - x1*y2)/(y1-y2);
    y3 = theEq(V(k),x3,coef,cst);
    if y1*y3 < 0
        x2 = x3;
        y2 = y3;
    else
        x1 = x3;
        y1 = y3;
    end % end IF
    error = abs(x2 - x1);
    itr = itr + 1;
    if itr > max_itr
        break
    end
end % end WHILE
Vagc(k)= x3;
Gain(k) = polyval(coef,x3);
dBm_Out(k) = dBm_In(k) + Gain(k); %Power Level in dBm
end % end FOR

format short
clf
%axis(Vagc)= [dBm_low,dBm_hi,0,3];
%plot(m,Gain),title('AGC Amplifier Gain'),ylabel('Gain, dB'),...
% xlabel('Input, dBm'),grid
%plot(m,Vagc),title('AGC Voltage'),ylabel('Volts, AGC'),...
% xlabel('Input, dBm'),grid
%subplot(2,2,2),plot(m,Vagc),title('AGC Voltage'),ylabel('Volts, AGC'),...
% xlabel('Input, dBm'),grid
plot(m,dBm_Out),title('Output, dBm'),ylabel('dBm Output'),...
    xlabel('Input, dBm'),grid
```

Filename: CLC5523.m

```
% Data Fit for CLC5523 Voltage Variable Amplifier
% Shunt Configuration ( A Control Input )
%Jeff Crawford July 26, 1999
%
%
function col = CLC5523

x=[0,0.1,0.2,0.3,0.4,0.5,0.6,0.7,0.8,0.9,1.0,1.1,1.2,1.3,1.4,1.5,1.6,1.7,1.8,
2.0,2.5,3.0];
y=[-80,-72,-66,-55,-43,-34.6,-27.32,-18.2,-9.29,-1.11,5.72,10.86,...
    14.54,17.085,18.676,19.553,19.933,20.073,20.121,20.142,20.152,20.172];
coef=polyfit(x,y,5);
format long e
xb = 0:0.05:3;
ybest=polyval(coef,xb);
clf
plot(xb,ybest,x,y,'o'),xlabel('Volts, AGC'),ylabel('Voltage Gain, dB'),...
    legend('Gain',4),grid
coef = coef;
```

Filename: theEq.m

```
% Solve for Required Gain v.s. Input Voltage
% Jeff Crawford July 23, 1999
%
function Eq = theEq(Vi,Vo,cf,cst)

Ka=cst(1);
Kc=cst(2);
Vr=cst(3);
Kd=cst(4);
Eq = Ka*((Vi*10^(polyval(cf,Vo)*0.05))*Kd+Vr) + Vo;
```

MatLab Files for Delayed AGC System

Filename: dblagc.m

```
% Analysis of Multi-Stage AGC Amplifier
% Jeff Crawford
% July 27, 1999
%
%Obtain most suitable coefficients to describe amplifier data
%
co1 = 0;
co1 = RF2604;
co2 = 0;
co2 = RF2604_NF;
%
format long e
dBm_low = -100;      dBm_hi = -30;      R = 50;
Ka=1e6;
Kc=1.0;
%R1 = 4000;
%R2 = 12000;
R1 = 4000;
R2 = 3000;
Vr= -1.4;
%Vr = -0.5;
%Vr = 0.1;
Vref = 0.01;
Gmix = -7;
Glina = 20; % Power gain of front-end amplifier
NF_lna = 2;
Kd=0.15;
max_itr=15;
itr=0;
cst = [Ka,Kc,Vr,Kd,R1,R2,Glina,Gmix,Vref];
Vagc1 = 0;
Vagc2 = 0;
Gain1 = 0;
Gain2 = 0;
dBm_Out = 0;
%
%format short;
```

```
% Input power level for AGC amplifier
m = dBm_low:1:dBm_hi;
V = sqrt(10.^(m*0.1)*0.001*R); %Volts rms
if length(Vagc1) > 0
    clear Vagc1
end
if length(Gain1) > 0
    clear Gain1
end
if length(dBm_Out) > 0
    clear dBm_Out
end
for k = 1:length(m)
    dBm_In(k) = dBm_low + k - 1;
    V_trial = -3.5;
    while V_trial < 0
        x1 = dbl_eqns(V(k),V_trial,col,cst);
        x2 = dbl_eqns(V(k),V_trial+0.05,col,cst);
        if x1*x2 < 0
            break
        end
        V_trial = V_trial + 0.05;
    end % end WHILE
    x1 = V_trial;
    x2 = V_trial + 0.05;
    error = 1e6;
    y1 = dbl_eqns(V(k),x1,col,cst);
    y2 = dbl_eqns(V(k),x2,col,cst);
    itr=0;
    while error > 0.0001
        x3 = (x2*y1 - x1*y2)/(y1-y2);
        y3 = dbl_eqns(V(k),x3,col,cst);
        if y1*y3 < 0
            x2 = x3;
            y2 = y3;
        else
            x1 = x3;
            y1 = y3;
        end % end IF
        error = abs(x2 - x1);
        itr = itr + 1;
        if itr > max_itr
            break
        end
    end % end WHILE
    Vagc2(k) = x3;
    Vagc1(k) = (-x3+Vr*(1+R2/R1))*R1/R2;
    Gain1(k) = polyval(col,(-x3+Vr*(1+R2/R1))*R1/R2);
    Gain2(k) = VV_Atn(x3);
    dBm_Out(k) = dBm_In(k)+Gmix+Gain1(k)+Gain2(k)+Glna;
end % end FOR
format short
NF = Calc_NF(Glna,NF_lna,Gain2,Gmix,Gain1,col);
clf
%
subplot(2,2,1),plot(m,Gain1),title('IF Gain'),ylabel('Gain, dB'),...
xlabel('Input, dBm'),grid
```

```

subplot(2,2,2),plot(m,Gain2),title('Attenuator Gain'),ylabel('Gain, dB'),...
    xlabel('Input, dBm'),grid
subplot(2,2,3),plot(m,Vagc1,m,Vagc2),title('IF Amp AGC Voltage,
Attn'),ylabel('Volts'),...
    xlabel('Input, dBm'),grid
subplot(2,2,4),plot(m,NF),title('Receiver NF, dB v.s. Input
Level'),ylabel('NF, dB'),...
    xlabel('Input, dBm'),grid

```

Filename: RF2604.m

```

% Data Fit for RF2604 AGC Amplifier
% Jeff Crawford July 26, 1999
%
%
function col = RF2604

x=[0,0.3,0.5,0.6,0.8,1.0,1.2,1.5,1.75,2.0,2.5,2.6,2.7,2.8,2.9,3];
y=[7,7.64,10.91,16.36,34.18,51.82,70.91,83.27,83.7,84.0,84.2,84.5,84.65,84.7,
84.75,84.8];
col=polyfit(x,y,9);
format long e
xb = 0:0.05:3;
ybest=polyval(col,xb);
clf
plot(xb,ybest,x,y,'o'),xlabel('Volts, AGC'),ylabel('Voltage Gain,
dB'),title...
    ('Response for RF2604 VV Amplifier'),grid

```

Filename: RF2604_NF.m

```

% Fits Noise Figure data for RF2604 AGC Amp as a function of Gain
%
% Jeff Crawford August 1, 1999
%
function co2 = RF2604_NF

x=[10,20,25,30,35,40,45,50,55,60,65,70,75,80,85,90,95];
y=[49.13,43.91,41.91,40,39.7,39.4,37.83,35.22,30.65,25.22,21.05,18,15.65,13.6
5,11.83,10,6.52];
co2=polyfit(x,y,7);
format long e
xb = 10:2:95;
ybest=polyval(co2,xb);
clf
plot(xb,ybest,x,y,'o'),xlabel('Gain, dB'),ylabel('Noise Figure, dB'),title...
    ('Noise Figure for RF2604 VV Amplifier'),grid

```

Filename: VV_Atten.m

```

% Data Fit for MaCom AT-201 Voltage Variable Attenuator
% Jeff Crawford July 26, 1999
% Updated With Additional Data Points Wednesday, July 28, 1999
%

```

```
function attn = VV_Attn(val)
x = 0;
y = 0;
x=[-6,-5,-4.5,-4,-3.5,-3.25,-3.2,-3.1,-3.0,-2.9,-2.77,-2.6,-2.42,-2.27,-
2.05,-1.9,-1.8,-1.7,-1.6,-1.5,-1];
y=[0,0,0,0,0,0,0,0,0,-5,-10,-15,-20,-25,-30,-30.5,-30.6,-30.7,-30.8,-30.9,-
31];
for m = 1:length(y)
    y(m) = y(m)-1.3;          % Minimum Attenuation of 1.3 dB
end
%co2=polyfit(x,y-1.3,13);    % Factor of -1.3 dB is Minimum Insertion Loss
%format long e
%xb = -5:0.05:-1.5;
%m = 1;
%x_val = -5;
%x_fit = 0;
%while x_val <= -1.5
%    x_fit(m) = x_val;
%    m = m + 1;
%    x_val = x_val + 0.1;
% end
%ybest=polyval(co2,xb);
attn = spline(x,y,val);
%clf
%plot(x,y,'o',xb,ybest,'+',xb,yspline),xlabel('Volts, AGC'),ylabel('Voltage
Gain, dB'),title...
% ('Response for MaCom AT-201 VV Attenuator'),legend('Original Data','Poly
Fit','Spline'),...
% axis([-4,-1.5,-35,10]),grid
```

Filename: dbl_eqns.m

```
% Solve for Required Gain v.s. Input Voltage
% Jeff Crawford July 23, 1999
%
function Eq = dbl_eqns(Vi,Vo,col,cst)
x1 = 0;
x2 = 0;
Ka=cst(1);
Kc=cst(2);
Vr=cst(3);
Kd=cst(4);
R1=cst(5);
R2=cst(6);
Glna=cst(7);
Gmix=cst(8);
Vref = cst(9);
%Eq = Ka*((Vi*10^(polyval(cf,Vo)*0.05))*Kd+Vr) + Vo;
%
% Vo is the same as Vagc2
%
Vagc2 = Vo;
Vagc1 = (R1/R2)*(-Vagc2+Vr*(1+R2/R1));
```

```
ed =  
Vi*10^(Glina/20)*10^(VV_Attn(Vagc2)/20)*10^(Gmix/20)*10^(polyval(co1,Vagc1)/20  
);  
Eq = (ed*Kd-Vref)*Ka*R2/R1 + Vr*(1+R2/R1) - Vagc2;
```

Filename: Calc_NF.m

```
% Calculate Noise Figure of System  
% Jeff Crawford August 1, 1999  
%  
function NF = Calc_NF(Glina,NF_lna,Gain2,Gmix,Gain1,co2)  
  
G1 = 10^(Glina/10);  
for m = 1:length(Gain2);  
    a = 10^(0.1*Nf_lna);  
    b = (10^(abs(Gain2(m))/10)-1)/G1;  
    G2 = 10^(Gain2(m)/10);  
    G3 = 10^(Gmix/10);  
    c = (10^(abs(Gmix)/10)-1)/(G1*G2);  
    d = (10^(polyval(co2,Gain1(m))/10) - 1)/(G1*G2*G3);  
    e = a + b + c + d;  
    NF(m) = 10*log10(e);  
end  
clf  
plot(m,NF),xlabel('Input Power, dB'),ylabel('Noise Figure, dB'),title...  
('Noise Figure for Receiver'),grid
```

¹ Radio Receivers, Gosling, William, Peter Peregrinus Ltd., Chapter 7, 1986

² "Simple Technique Yields Errorless AGC Systems," Bullock, Scott R., *Microwaves & RF*, August, 1989, pp. 85-93

³ "Schottky Barrier Diodes for General Purpose Applications," Technical Data from Hewlett Packard, 1N5711

⁴ "Schottky Barrier Diode Video Detectors," Application Note 923, Hewlett Packard

⁵ Electronic Communication Systems, Zeines, Ben, Prentice-Hall, 1970, Chapter 10

⁶ Microwave Solid-State Circuits and Applications, Chang, Kai, John Wiley & Sons, pp. 153-158, 1994