SYSTEM DESIGN OF A 23 GHZ MICROWAVE RECEIVER

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ABSTRACT

The rapid increase of multimedia services and the liberalization of the telecommunication market have created demands for broadband wireless systems. Public broadband services over radio, however, require large bandwidth that is available only at relatively high microwave frequencies. Unfortunately, rain is a dominant source of attenuation at higher frequencies. Rain affects on microwave systems are more critical in tropical region. This paper presents the system design of a 23 GHz receiver for point-to-point microwave link. The linearity requirements for receiver need to be considered for the different level of power received during clear sky and raining. The designed system is simulated using Advanced Design System (ADS) from Agilent’s for simplify the process of component specifications determination and performance analysis. The design of receiver is the proper selection of microwave components to meet the European Telecommunications Standards Institute (ETSI) recommendations for point-to-point equipment in fixed radio systems operating at 23 GHz [1].

Keywords- receiver system, point-to-point microwave link, 23 GHz, linearity.

1. INTRODUCTION

The goal of a receiver design is to optimise its performance in the presence of interferers. Electromagnetic radiation from communication systems, broadcast systems, radar, power lines, and the undesired signals can be picked up by a receiver. The interference is always presents and could be severe in urban areas.

As a receiver operates at higher frequency especially in the 23 GHz band, the rain attenuation needs to be considered. The receiver should have sufficient power received to overcome the effect of rain attenuation and propagation path loss.

The RF power at a receiver will be a function of the distance and the geography between the transmitter and receiver. The power law effect is due to the power loss of an electromagnetic wave travelling through free space in a line of sight path from transmitter to receiver [2].

There are two situations to be considered: The minimum power received and maximum power received. If the power received is lower than the minimum value, the noise dominates but if it is greater than the maximum value, the system operated in saturation region.

The designed system is simulated in ADS communication software for linearity performance measurement and analysis. The analysis include system gain compression, third order intercept point (IP3) and spurious response. The purpose of this study is to design a receiver system follows the ETSI recommendation.

2. RECEIVER BLOCK DIAGRAM

The receiver block diagram shows in figure 1 consists of a RF front end, a first IF (Intermediate Frequency), and a second IF. RF input signal is down converted from 22.224 GHz to 140 MHz with 20 MHz bandwidth. The nominal noise figure of the system is 3dB, which provided by noise figure of the first stage.
The system will be installed with 5km distance and for 4-states modulation scheme (QPSK) modem. The free space loss, $L_{FS}$ is 133.3 dB \[3\]. If power transmitted is 30 dBm with gain antennas for transmitter and receiver 38 dB, the power received in clear sky about –28 dBm. But, during rain situation the power received will drop significantly to –90 dBm. The previous study conducted by Wireless Communication Research Laboratory Universiti Teknologi Malaysia \[4\] has measured the rain attenuation for 23 GHz microwave signal in Malaysia. The measurement results show that the rain attenuation considered for 0.01 percentage of time is 62 dB for 5 km.

### 3. INTERMODULATION

The intercept point, measured in dBm, is a figure of merit for intermodulation product suppression. A high intercept point indicates a high suppression of undesired intermodulation products. Intermodulation occurs when two or more sinusoidal signals are applied to a non-linear device. The output will consist of the fundamentals, harmonics, and other spurious frequencies. Intermodulation products appear as soon as the transfer characteristics become non-linear.

The third-order intermodulation (IM3) products are usually of primary interest because of they have relatively large magnitude and difficulty to filter from the desired mixer output if their frequency separation is small \[5\].

Figure 2 is the simulation results for the third order intercept point (IP3) analysis. The IM3 tones are at ±3.5 MHz separations from the carriers.

The carrier-to-interference ratio (C(IM3)) in dB is calculated by using C(IM3) equations. The C(IM3) ratio is the difference between the IF power output and IM3 power output. They give suppression about 108dB below the carrier with power input –64.5 dBm.

In ETSI recommendation, assume at worst case, the minimum detectable signal (MDS) or threshold with $10^{-6}$ BER is -83.5 dBm. Some ETSI documents call for a direct IP3 test at threshold, required two signals at +19 dB relative to the threshold. Correspond to 1 dB degradation thermal noise; the carrier-to-interference ratio (C/I) at the receiver is 23 dB. The C(IM3) measured in the simulation is 108 dB, therefore the designed system meets the requirements as determined in ETSI standard.

The IP3 also determines the spurious free dynamic range (SFDR) of a receiver. SFDR is the difference in dB between the maximum input and minimum input of the receiver. The minimum input or MDS is defined as 3 dB above the noise floor \[6\]. The noise floor of the receiver system is -101 dBm, which give the MDS of –98 dBm. The maximum input power ($P_{in,max}$) allowed for the system is the input power($P_{IP3}$) that causes the IM3 power level equal to the noise floor ($N_{floor}$). $P_{in,max}$ in dBm can be expressed in equation1.
\[ P_{in,\text{max}} = \frac{2P_{\text{IP3}} + N_{\text{floor}}}{3} \]  

Equation (1) is modified for calculating the SFDR in dB.

\[ SFDR = P_{in,\text{max}} - P_{in,\text{min}} = \frac{2}{3} (P_{\text{IP3}} - \text{MDS}) \]  

Table 1 shows the input IP3 and the C_IM3 with different input power. The input power is swept from –100dBm to 30 dBm with 5 dB step. The C_IM3 shows the relative value of output power to the IM3 at different input power. At maximum input power, the C_IM3 is 30 dB. This value doesn’t exceed the limit of C/I in ETSI standard even though the input power is increased from –100 dBm to –30 dBm.

Table 1. Input IP3 and the C IM3 with power input level from –100 dBm to –30 dBm

<table>
<thead>
<tr>
<th>p_{in}</th>
<th>ip3_{in,upper}</th>
<th>C_{IM3,upper}</th>
</tr>
</thead>
<tbody>
<tr>
<td>-100.000</td>
<td>-13.258</td>
<td>172.090</td>
</tr>
<tr>
<td>-95.000</td>
<td>-13.258</td>
<td>162.090</td>
</tr>
<tr>
<td>-90.000</td>
<td>-13.258</td>
<td>152.090</td>
</tr>
<tr>
<td>-85.000</td>
<td>-13.258</td>
<td>142.090</td>
</tr>
<tr>
<td>-80.000</td>
<td>-13.258</td>
<td>132.090</td>
</tr>
<tr>
<td>-75.000</td>
<td>-13.258</td>
<td>122.090</td>
</tr>
<tr>
<td>-70.000</td>
<td>-13.258</td>
<td>112.090</td>
</tr>
<tr>
<td>-65.000</td>
<td>-13.258</td>
<td>102.090</td>
</tr>
<tr>
<td>-60.000</td>
<td>-13.258</td>
<td>92.090</td>
</tr>
<tr>
<td>-55.000</td>
<td>-13.272</td>
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<td>62.042</td>
</tr>
<tr>
<td>-40.000</td>
<td>-13.400</td>
<td>51.937</td>
</tr>
<tr>
<td>-35.000</td>
<td>-13.707</td>
<td>41.617</td>
</tr>
<tr>
<td>-30.000</td>
<td>-14.670</td>
<td>30.696</td>
</tr>
</tbody>
</table>

For the power input at –90 dBm and the N_{floor} at –101 dBm, this yield the P_{in,max} of –42.5 dBm from (2). The required SFDR is 55.5 dB.

4. SYSTEM GAIN COMPRESSION

The input power level at which the loss increases by 1 dB at the output, called the 1 dB compression point. In a receiver, operation is normally in a region where the output power is linearly proportional to the input power.

Figure 3 is the simulation result for compression analysis. The RF input power is swept from –80 dBm to 0 dBm with 5 dBm step. A linear output response line, IF output power compression and gain compression are shown. The receiver experienced less than 1dB compression at input power of –24 dBm. The system gain is 37 dB in the range of power input.

5. RECEIVER SPURIOUS RESPONSE

Receiver spurious responses are defined to be an apparent on channel response to an undesired signal or group of signals. Spurious responses are caused by non-linearities in the receiver system. Intermodulation is a type of spurious response.

The spurious response for minimum and maximum input power is shown in figure 4 and figure 5. In figure 4, the IF frequency is marked “IF” while the highest spur near 140 MHz is marked “Spur”. In figure 5, The IF frequency is marked “IF1” while the highest spur near 140 MHz is marked “Spur1”.
The highest spurious response near 140 MHz is LO frequency at 2.264 GHz. The lowest level relative to the IF frequency is 25.656 dB.

**6. CONCLUSION AND FUTURE WORK**

Microwave receiver system for point-to-point microwave link is performed with Agilent ADS Communication System Designer. The third order intercept point (IP3), gain compression and spurious response, which determine the linearity of a receiver, is measured and analysed in ADS.

The system simulation result shows that the receiver performance follows ETSI recommendation. The C_IM3 and spurious responses not exceed the limit of C/I in ETSI standard even though the input power increased. Simulation’s results also provide a receiver system designed with gain compression less than 1 dB.

As future work, the system performance with modulated signal and BER performance is required to be considered. Prototype of a 23 GHz receiver will also be developed. Further improvement is required to enhance receiver performance.

**7. REFERENCES**


