System Level Analysis of A 23GHz Transmitter Design For Point To Point Microwave Link

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***Abstract*- The restricted spectrum frequency and the narrow bandwidth allocated by regulatory organizations to wireless users impacts the design of the RF front end. Narrowband amplification and filtering to avoid leakage to adjacent bands is required for transmitter design. Power spectrum of transmitter must not exceed the limits of spectral power density [1]. This paper presents a 23GHz transmitter system for point-to-point microwave link. Linearity requirements for the transmitter need to be considered in order to have high power transmit. The system is designed with Advanced Design Software (ADS). A 23 GHz transmitter comprises a double conversion up-converter. The simulation result of power transmit is 27.576 dBm. This is obtained over the 22.999 – 23.549 GHz frequency range. The design of transmitter is the proper choosing and arrangement 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- transmitter design, point-to-point microwave link, 23 GHz, linearity, system level.

I. Introduction

A transmitter is an important subsystem in a wireless system. The specifications for a transmitter depend on the applications. For long -distance transmission, high power and low noise are important. For space or battery operating systems, high efficiency is essential. For communication systems, low noise and good stability are required [2].

The rapid increase of multimedia services and the liberalization of the telecommunication market have created demands for broadband wireless systems. A well-designed wireless access system reduces the need of a complex, fixed infrastructure. Moreover, it offers flexible connection capacity that can dynamically be adapted to the immediate needs of the end-user, thus providing a cost-efficient solution. Public broadband services over radio, however, require bandwidth that is available only at relatively high microwave frequencies [3].

Non-linearity effect is due to the implementation of non-linear components. The non-linearity specifications of each transmitter component is analysed with ADS simulation software. The analysis includes system compression, spurious response, power transmit and intermodulation distortion. In the simulation, the specifications of microwave components are optimised by using the optimisation simulator controller.

The minimum performance parameters for point-to-point equipment in terrestrial digital fixed service radio communications systems operating at 23 GHz has been specified in European Telecommunications Standards Institute (ETSI) recommendation.

II. Transmitter Design

A block diagram of a double stage up-conversion transmitter is shown in Fig.1. The transmitter consists of local oscillators, up-converters (mixers), filters and power amplifier. IF input is 350 MHz of 0 dBm input power then double up-converted to 23.274 GHz with transmission bandwidth 550 MHz. The power amplifier (PA) is used to increase the output power before transmitted by antenna. The maximum output power measured in the simulation is +27.576 dBm. According to ETSI recommendation, the transmitter power range for 23 GHz shall not exceed +30dBm (including tolerance) as shown in Fig.2. Thus, this transmitter design meets the ETSI requirement.

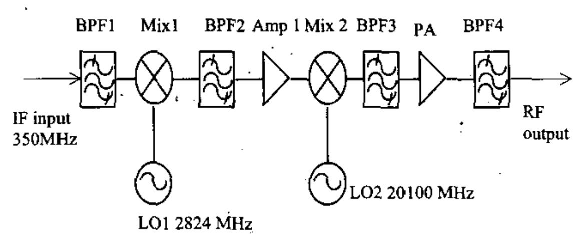
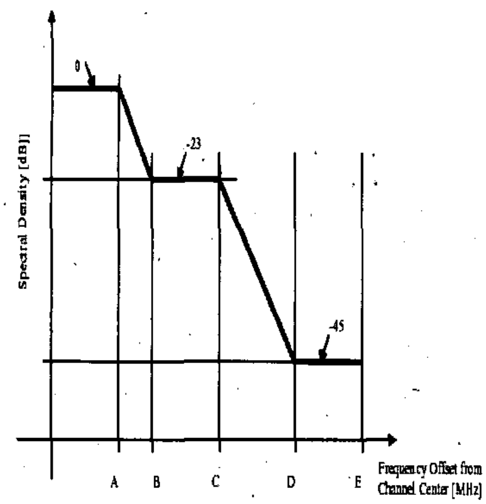


Fig.1 Block diagram for a double stage up-conversion transmitter

Fig. 2 shows the transmitter spectrum mask for 4-state modulation scheme. The spurious response is not allowed to exceed the limit of the mask. The highest spurious level is 23 dB down from the carrier frequency.

Figure for Type A (ETSI):



Point	A	B	C	D	E
Value in MHz	11C/28	19C/28	25C/28	45C/28	5C/2

Note: C is defined as channel size in MHz (i.e. 28 MHz).

Fig.2 Spectrum Mask for 2x2.048 QPSK Signal [1].

III. System Compression

The input power level at which the loss increases by 1 dB, called the 1 dB compression point. Therefore, 1dB compression point analysis determines the maximum output power allowed for the transmitter. The output P_{1dB} for every component placed in the transmitter system will effect to the overall system compression and cause the transmit power lower than real value. Normally, the maximum output power for every component is determined by its linear output power level (P_{linear}), which is obtained by adding the gain or subtracting the loss of each component. with the input power level. How ever, every component contributes gain compression therefore the transmitter is forced to compress the output power. The output P_{1dB} for every component determines its maximum output power. Consequently, in order to have maximum power transmit, each component needs to have higher output P_{1dB}.

The compression value is the difference of linear output power level (P_{linear}) with measured output power level (P_{out}). The input power level is swept within a range, from linear to saturation range (-30dBm to 20dBm). The system compression for designed system at input power level of 0 dBm is provided in Fig.3. The component parameters are listed in Table 1.

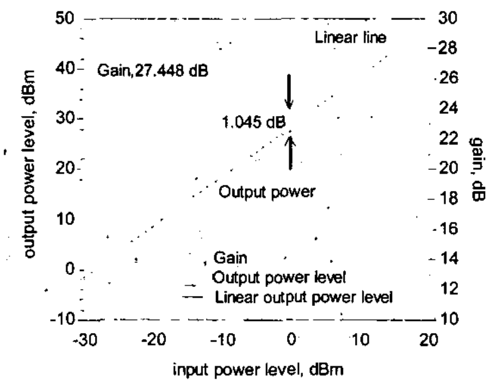


Fig.3 System compression for 23 GHz transmitter design

Fig.3 shows that the system design compression is 1.045 dB with output power 27.448 dBm. This result is lower than the predicted value of 28.493dBm. Overall gain budget is 27.448 dB.

Table 1 provides the compression level analysis for every component in transmitter. The input power of IF frequency is 0 dBm. Those components are available in ADS component library. P_{1dB} of each component is adjusted in order to have gain compression less than 1 dB. All filters are assumed operating in linear region. This is because there is no P_{1dB} compression parameter available in ADS. Data sheet for filters available in market do not give the specified parameter for P_{1dB} compression.

Table 1 Compression analysis for every component in transmitter design

Comp	*Gain/ Loss(dB)*	*P_{linear} (dBm)*	*P_{out} (dBm)*	*P_{1dB} (dBm)*
BPF1	- 0.5	-0.5	-0.5	-
Mix1	- 4.5	-5.0	-5.057	+3
BPF2	- 0.5	-5.557	-5.557	-
Amp1	+ 15	9.443	9.319	+17
Mix2	- 5	4.319	4.056	+7
BPF 3	- 1	3.056	3.056	-
PA	+ 26	29.056	28.448	30
BPF 4	- 1	27.448	27.448	-

Table 1 shows that every component contributes compression to the system. Spurious products generated in the system cause the compression value of each component are different from the real assumption. From simulation results, the component that experiences the most compression is PA (power amplifier). This is because the PA amplifies the harmonic and intermodulation products generated from the previous stage besides the fundamental signal. The maximum compression value for PA available in market is +30 dBm.

In order to increase the output power of the transmitter and to achieve compression levels less than 1 dB is with increasing the third order intercept point (TOI) parameter of power amplifier. TOI of power amplifier is increased from 41dB to 45dB[4]. This improvement gives 0.918 dB compression level as shown in Fig.4. Output power of transmitter will be increased 0.128 dB. Therefore, total output power is 27.576 dB.

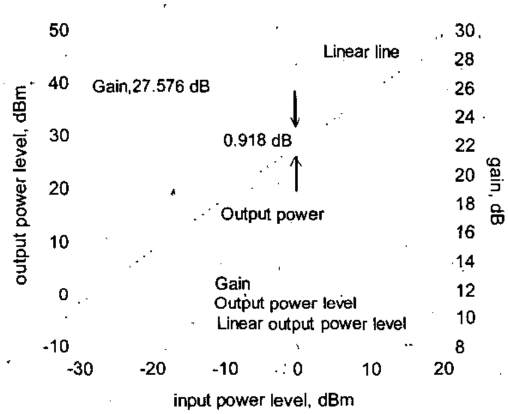


Fig.4 System compression for 23 GHz transmitter with increasing TOI of power amplifier

IV. Spurious Response

For a transmitter with double up-converter and power amplifier, many other spurious signals could exist at the output due to the nonlinearity of these components. The nonlinearity will cause two signals to generate many mixing and intermodulation product.

The spurious response analysis determines if there is any high power frequency response near to the transmitting frequency. The difference of power level between the transmitting frequency and the highest spurious frequency is known as spurious suppression. A single tone CW (continuous wave) is applied as a signal source. Harmonic spurs are integer multiples of CW output. As a result, some harmonics and intermodulation products appeared in the spectrum due to mixing process.

Fig.5 shows that the transmitting frequency and the highest spurious marked as " P_{out}" and "S_{purs}" respectively. The highest spurious appeared in the transmitter system is at -43.86 dBm of 22.924GHz. This spurious frequency is the mixing products of $f_{LO1}+f_{LO2}$. The spurious suppression is about –71dBm below transmitting frequency. This transmitter spurious suppression meets the CEPT standard, which has value less or equal to –47dBm [5].

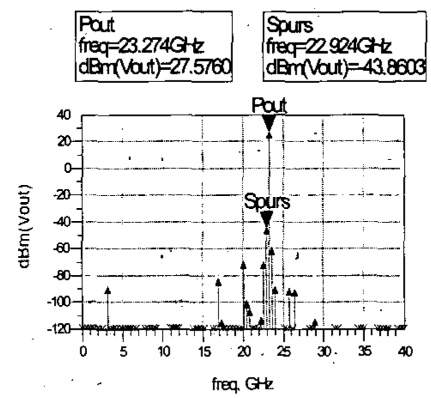


Fig.5 Spurious Response in the transmitter

V. Power Transmit

This simulation is performed with modulated QPSK source with carrier frequency of 350 MHz. The total bit-rate processed by the QPSK modem is 4.096 Mbps. This transmitter applies a fixed output power level. Fig. 6 shows the comparison between the spectrum mask (ETSI) and the power transmit measured in simulation. To compare with spectrum mask, the output spectrum is normalised with the power level of carrier. As a result, the power transmit does not exceed the spectrum mask specified in ETSI requirement [1].

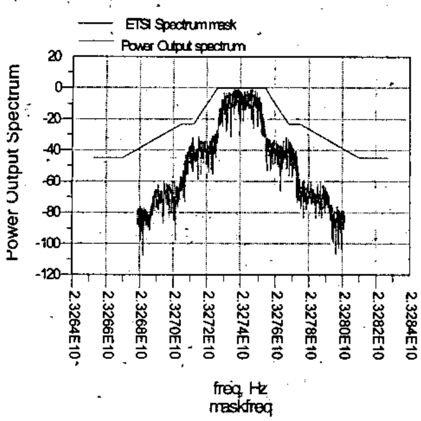


Fig.6 Output spectrum for 23 GHz transmitter and spectrum mask limitation

VI. Intermodulation Distortion

In ETSI recommendation, there are no specifications mentioned for transmitter in two CW tones testing in order to measure the TOI and carrier to intermodulation distortion (CIMD) of the system. To measure the system TOI, two CW tones with spacing of 3.5 MHz at 0 dBm are applied as the transmitter IF input.

TOI for every component of the transmitter system with its CIMD level is shown in Table 2. Referred to [4], TOI for mixer and amplifier are required 15 dB and 11 dB above the components' output P_{1dB} respectively. For filters, there are no TOI parameters available in ADS. Thus, filters are assumed operating in linear. TOI for mixer and amplifier of transceiver are designed to meet [4] requirement. Especially for power amplifier, the TOI parameter is increased more than 11 dB above the power amplifier's output P_{1dB}. P_{out} is measured output power level for CW tones, P_{IM3} and cumulative TOI are measured IM3 power level and measured cumulative TOI for every component respectively.

Table 2 Pout, P_{IM3} and T OI at output of every component in 23 GHz transmitter

Comp	P_{out} (dBm)	TOI (dBm)	Cumulative TOI (dBm)	P_{IM3} (dBm)
BPF1	-0.536	--	--	--
Mix1	-5.267	+18	+14.468	-44.736
BPF2	-5.767	--	+13.968	-45.236
Amp1	+8.869	+28	+24.919	-23.231
Mix2	+2.550	+22	+12.828	-18.007
BPF3	+1.550	--	+11.828	-19.007
PA	+26.005	+45	+33.990	+10.038
BPF4	+25.005	--	+32.990	+9.038

The cumulative TOI for the system is + 32.990 dBm. The system TOI does not meet the [4] requirement, which is 11 dB above the P_{1dB} of 27.576 dBm. This system operates in compression region as determined in compression analysis.

VII. Conclusion and Future Works

System level design of Microwave transmitter system for point-to-point microwave link is performed with ADS Communication System Designer. The system compression, spurious response, power transmit, and intermodulation distortion for transmitter are determined and analysed. To achieve a high power transmit, third order intercept point (TOI) of power amplifier is optimised to maximum value. Maximum output power of transmitter must not exceed the limit of power spectrum as required in ETSI standard. Spurious rejection of the transmitter design meets CEPT standard of less than –47dBm.

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

VIII. References

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