

The third property gives the range of the similarity parameter. In particular, two scattering matrices are completely similar if and only if both matrices only have a constant difference after one is rotated an angle.

The fourth property tells us that the sum of the similarity parameters between a scattering matrix and three pairwise non-similar scattering matrices equals 1. For four arbitrary scattering matrices, one knows from this property that there exist at least two scattering matrices with a similarity parameter greater than zero.

Extraction of characteristics of a target: As an application, the similarity parameter can be used to extract some characteristics of a target.

Setting $[S] = [S_1]$ and $[S_2] = \text{diag}(1, 1)$, we obtain the parameter of similarity to the scattering matrix of a plate (or sphere) from eqn. 5 as

$$r_1 = r([S], \text{diag}(1, 1)) = \frac{|s_{HH}^0 + s_{VV}^0|^2}{2(|s_{HH}^0|^2 + |s_{VV}^0|^2 + 2|s_{HV}^0|^2)} = \frac{|s_{HH} + s_{VV}|^2}{2(|s_{HH}|^2 + |s_{VV}|^2 + 2|s_{HV}|^2)} \quad (8)$$

where s_{HH} , s_{HV} and s_{VV} are the elements of the scattering matrix $[S]$. For an N -target scattering matrix

$$[S_N] = \begin{bmatrix} a & b \\ b & -a \end{bmatrix}$$

it is easy to check that

$$r(\text{diag}(1, 1), [S_N]) = 0 \quad (9)$$

From eqn. 5, we derive the parameter of similarity to the diplane scattering matrix $\text{diag}(1, -1)$ as follows:

$$r_2 = r([S], \text{diag}(1, -1)) = \frac{|s_{HH}^0 - s_{VV}^0|^2}{2(|s_{HH}^0|^2 + |s_{VV}^0|^2 + 2|s_{HV}^0|^2)} \quad (10)$$

where s_{HH}^0 , s_{HV}^0 and s_{VV}^0 are given by eqn. 2. For a symmetric target scattering matrix $[S_S]$, we know from [1, 5] that

$$[S_S^0] = \begin{bmatrix} s_{HH}^0 & 0 \\ 0 & s_{VV}^0 \end{bmatrix} \quad (11)$$

It is easy to prove from eqns. 8 and 10 that

$$r(\text{diag}(1, 1), [S_S]) + r(\text{diag}(1, -1), [S_S]) = 1 \quad (12)$$

The parameters of similarities to the scattering matrices of a left and a right helix

$$[H_L] = \begin{bmatrix} 1 & i \\ i & -1 \end{bmatrix} \quad \text{and} \quad [H_R] = \begin{bmatrix} 1 & -i \\ -i & -1 \end{bmatrix}$$

are

$$r_3 = r([S], [H_L]) = \frac{|(s_{HH}^0 - s_{VV}^0) - 2is_{HV}^0|^2}{4(|s_{HH}^0|^2 + |s_{VV}^0|^2 + 2|s_{HV}^0|^2)} = \frac{|(s_{HH} - s_{VV}) - 2is_{HV}|^2}{4(|s_{HH}|^2 + |s_{VV}|^2 + 2|s_{HV}|^2)} \quad (13)$$

$$r_4 = r([S], [H_R]) = \frac{|(s_{HH}^0 - s_{VV}^0) + 2is_{HV}^0|^2}{4(|s_{HH}^0|^2 + |s_{VV}^0|^2 + 2|s_{HV}^0|^2)} = \frac{|(s_{HH} - s_{VV}) + 2is_{HV}|^2}{4(|s_{HH}|^2 + |s_{VV}|^2 + 2|s_{HV}|^2)} \quad (14)$$

For an arbitrary scattering matrix $[S]$, it is easy to check from eqns. 8, 13 and 14 that

$$r([S], \text{diag}(1, 1)) + r([S], [H_L]) + r([S], [H_R]) = 1 \quad (15)$$

This result can also be proved by using the fourth property of the similarity parameter because

$$r(\text{diag}(1, 1), [H_L]) = r(\text{diag}(1, 1), [H_R]) = r([H_L], [H_R]) = 0 \quad (16)$$

In particular, letting $[S] = [S_N]$, one knows from eqns. 9 and 15 that

$$r([S_N], [H_L]) + r([S_N], [H_R]) = 1 \quad (17)$$

where $[S_N]$ denotes the scattering matrix of an N -target.

From eqn. 5, we can also derive the parameters of similarities to other scattering matrices. For example, substituting $[S_2] = \text{diag}(1, 0)$ into eqn. 5, we obtain the parameter of similarity to the scattering matrix of a wire as

$$r_5 = r([S], \text{diag}(1, 0)) = \frac{|s_{HH}^0|^2}{|s_{HH}^0|^2 + |s_{VV}^0|^2 + 2|s_{HV}^0|^2} \quad (18)$$

The above parameters are useful for extracting some characteristics of a target. When we analyse single reflections and double reflections from a target, the parameters r_1 and r_2 are important; when we consider the helicity of a target, r_3 and r_4 are useful.

Conclusion: The similarity parameter between two scattering matrices has been presented. This parameter is not only independent of the spans of the scattering matrices, but also independent of the target orientation angles. From the definition of this parameter, we have derived the parameters of similarities to the scattering matrices of a plate (sphere), a diplane, a wire and two helices, which are very convenient for analysing characteristics of a radar target.

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Optimum window and frame size for IrDA links

A.C. Boucouvalas and V. Vitsas

For the first time, a simple formula is derived for the throughput, optimum window and frame sizes of the IrDA IrLAP protocol. For 16Mbit/s links the use of the proposed window size of 127 frames makes the link performance worse at a higher line BER. The significance of the minimum turnaround time on the throughput is studied.

Introduction: IrDA infrared wireless ports are populating millions of products such as laptops, printers, personal digital assistants and mobile phones every year [1]. The data rate options range from 115.2kbit/s, 1.152Mbit/s, 4Mbit/s and 16Mbit/s. The IrDA standard specifies link BER less than 10^{-8} for a link operating from 0 to at least 1m. The hardware is driven by the IrDA link layer protocol IrLAP [2]. This work is concerned with the study of maximising the link throughput by selecting optimum parameters for IrLAP. The parameters for maximum throughput for any BER are of great interest to link designers. Performance analysis of IrLAP protocol using the concept of virtual transmission time was presented in [3] and the significance of the window size N and other link parameters was presented in [4]. We use a new analytical model, which allows the derivation of a simple and intuitive equation for the IrLAP throughput. Based on this equation, we derive optimum parameters for frame length and window size. The results give insights for the optimum control of the link for maximum throughput.

Table 1: Parameters used in modelling IrLAP throughput

Symbol	Parameter description	Unit
C	Link data baud rate	bits/s
p_b	Link bit error rate	—
p	Frame error probability	—
l	I-frame message data length	bits
l'	S-frame length/I-frame overhead	bits
t_l	Transmission time of an I-frame	s
t_s	Transmission time of an S-frame	s
t_{ra}	Minimum turn-around time	s
t_{ack}	Acknowledgment time	s
t_{Fout}	F-timer time-out period	s
D_f	Frame throughput	frames/s
D_b	Data throughput	bits/s

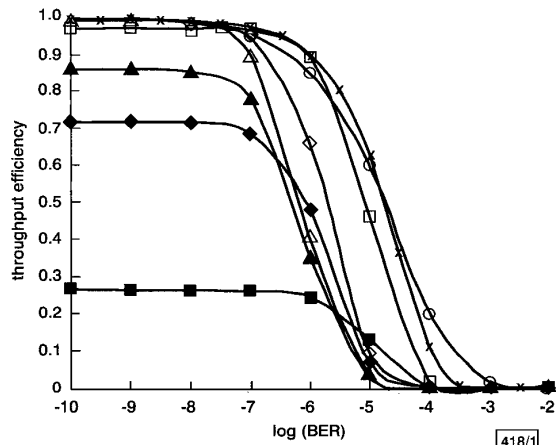


Fig. 1 Throughput against BER for 16Mbit/s link

$l = 16\text{kbits}$
 $\triangle$ $N = 127, t_{ra} = 0.1\text{ms}$ $\blacktriangle$ $N = 127, t_{ra} = 10\text{ms}$
 $\diamond$ $N = 50, t_{ra} = 0.1\text{ms}$ $\blacklozenge$ $N = 50, t_{ra} = 10\text{ms}$
 $\square$ $N = 7, t_{ra} = 0.1\text{ms}$ $\blacksquare$ $N = 7, t_{ra} = 10\text{ms}$
 $\times$ optimum N $\circ$ optimum l

Analysis: Table 1 includes a list of symbols used for our analysis. The symbols for t_s , t_l , t_{ack} , p and D_b are defined as follows:

$$t_s = \frac{l'}{C} \quad t_l = \frac{l + l'}{C} \quad t_{ack} = 2t_{ra} + t_s$$

$$p = 1 - (1 - p_b)^{l+l'} \quad D_b = lD_f \quad (1)$$

To calculate the link throughput, a mathematical model is developed using the concept of 'window transmission time'. This determines the number of correct in-sequence frames received in a complete N frame window transmission and the time needed for that transmission.

We derive that the frame throughput D_f is given by

$$D_f = \frac{1-p}{p} \frac{(1 - (1-p)^N)}{Nt_l + p(t_{Fout} + t_s) + t_{ack}} \quad (2)$$

Intuitively, eqn. 2 reveals that D_f is given by the number of correct frames transmitted before an error occurs (term $(1-p)/p$) times the probability of an error in a window (term $(1 - (1-p)^N)$) divided by the average window transmission time.

Differentiating eqn. 2, and to a very good approximation we can derive the following optimum values for window size N and frame size l .

$$N_{opt} = \sqrt{\frac{2t_{ack}C}{l^2p_b}} \quad l_{opt} = \sqrt{\frac{2(Nl' + t_{ack}C)}{N^2p_b}} \quad (3)$$

The optimum values (eqn. 3) reveal that maximum throughput is achieved when the product of the probability of an error in the window ($\approx Nlp_b$) times the number of bits to be retransmitted due to the error (which on average is half the window ($Nl/2$)) must be equal to the acknowledgement time in bits ($t_{ack}C$) plus the number of the overhead bits in the window (Nl').

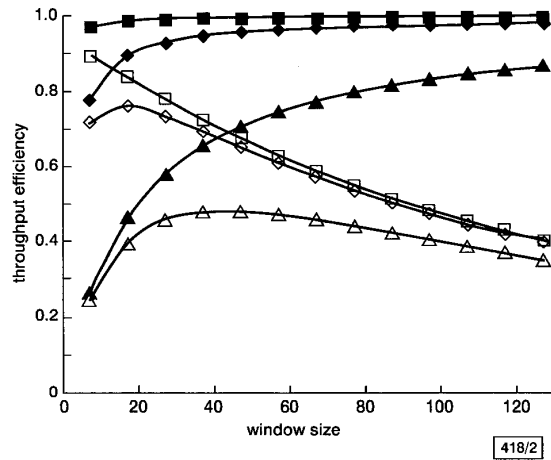


Fig. 2 Throughput against maximum window size for 16Mbit/s link

$l = 16\text{kbits}$
 $\triangle$ $\text{BER} = 10^{-6}, t_{ra} = 10\text{ms}$ $\blacktriangle$ $\text{BER} = 10^{-10}, t_{ra} = 10\text{ms}$
 $\diamond$ $\text{BER} = 10^{-6}, t_{ra} = 1\text{ms}$ $\blacklozenge$ $\text{BER} = 10^{-10}, t_{ra} = 1\text{ms}$
 $\square$ $\text{BER} = 10^{-6}, t_{ra} = 0.1\text{ms}$ $\blacksquare$ $\text{BER} = 10^{-10}, t_{ra} = 0.1\text{ms}$

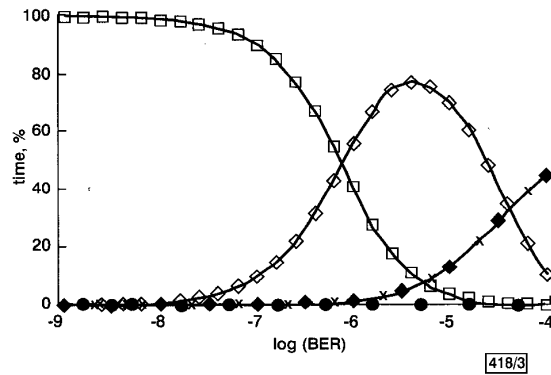


Fig. 3 Time allocation of various IrLAP tasks against BER

Link rate = 16Mbit/s, packet size = 16kbits, $t_{ra} = 0.1\text{ms}$, $N = 127$ frames
 $\square$ useful data transmission (throughput efficiency)
 $\diamond$ retransmission of correctly received out of sequence frames
 $\times$ retransmission of error frames
 $\blacklozenge$ t_{Fout} timer expiration
 $\bullet$ reversing link direction (hardware latency)

Results: Using eqn. 2, we plot Fig. 1, which shows throughput efficiency against BER for a 16Mbit/s link for various values of N and t_{ra} . Increasing the window size decreases the link turnaround frequency. For a low BER, increasing the window size results in significant throughput improvement for large t_{ra} and a smaller

improvement for small t_{ia} values. The price we pay for using large window sizes is that throughput becomes sensitive to an increase in the BER. This is because following an erroneous frame will result in a large number of frames being transmitted out of sequence in the same window. By selecting a small window size (e.g. window size 7 in Fig. 1) the link becomes resistant to an increase in BER and still offers a high throughput efficiency of 0.968 at a low BER and $t_{ia} = 0.1$ ms. Throughput against window size for various BER values and t_{ia} is shown in Fig. 2. The throughput significantly decreases with window size increase for a high BER (10^{-6}) and slightly increases for a low BER (10^{-10}). The increase or decrease level depends on the values of t_{ia} .

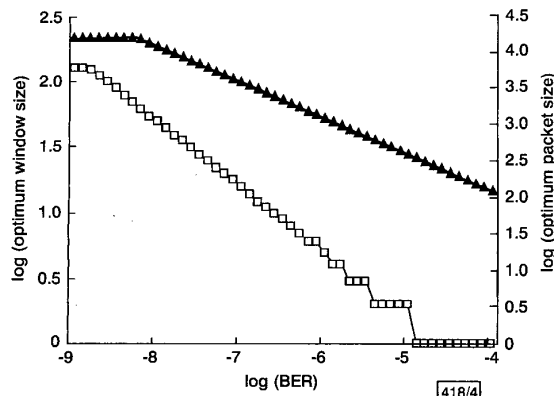


Fig. 4 Optimum window for $l=16$ kbits and optimum packet size for $N=127$ against BER

Link rate = 16 Mbit/s, $t_{ia} = 0.1$ ms
 □ optimum window size
 ◆ optimum packet size

Fig. 3 shows that time allocation of various IrLAP tasks against BER. It is obvious that, for a wide range of BER (from 10^{-8} to 10^{-4}), the key factor that reduces throughput is the retransmission of correctly received out-of-sequence frames. This is a limitation of the IrDA IrLAP protocol when non-optimum window size is used. For a high BER, although the link is still operational, optimum values for N become of key importance if maximum throughput is to be achieved. Only at a very high BER, $> 10^{-4}$, the main factor causing decrease in throughput is the retransmission of frames with errors. Fig. 3 reveals that the effect of t_{Fout} timer is significant for a high BER. Fig. 3 also shows that, if a small t_{ia} value is implemented, in comparison to t_b , the throughput is not significantly affected. Fig. 4 shows the optimum frame size and optimum window size for any BER resulting in maximum throughput. The corresponding optimum throughput is shown in Fig. 1.

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High breakdown voltage GaN HFET with field plate

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A novel high breakdown voltage GaN HFET with a field plate (FP GaN HFET) to form a gamma-shape gate is presented. The use of the field plate significantly reduces the field strength under the gate near the drain side. Simulation results show that the peak electric field of the device is reduced from 1.2×10^6 V/cm to 0.9×10^6 V/cm for the particular structure used. A high breakdown voltage (over 110 V) is achieved and the average ratio of BV_{gd} over BV_{gs} reaches a value of 2.4, compared to that of only 1.038 for a conventional GaN HFET.

Introduction: GaN HFETs (heterojunction field effect transistors) are excellent candidates for high-power microwave applications. In recent years, rapid progress has been made in achieving high breakdown field (voltages) and high current densities [1–3]. Conventional methods to increase the breakdown voltage usually involve increasing the gate-drain distance; however, this increases the drain series resistance and hence degrades the power performance of the devices [4, 5]. Furthermore, increasing the gate-drain distance only works up to a certain distance, beyond which an additional increase in the distance will not improve the breakdown voltage further. In this Letter, we use a novel GaN HFET device structure with a field plate to form an asymmetric gamma gate (FP GaN HFET) to increase the breakdown voltage. Our simulation results show that the peak electric field of the device is reduced from 1.2×10^6 V/cm to 0.9×10^6 V/cm. The experiment results fit the simulation results well.

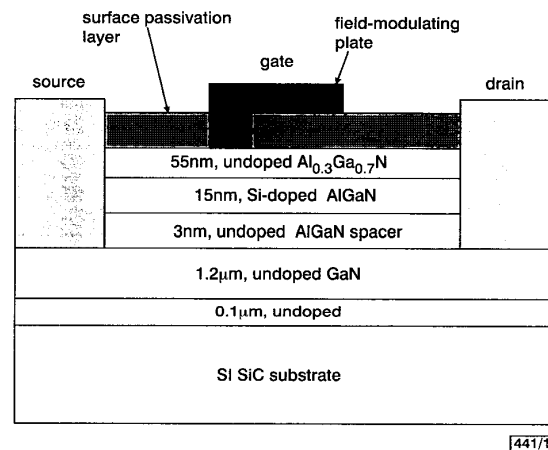


Fig. 1 Schematic diagram of FP GaN HFET

Layered structure is one of several structures used. No major differences in results were seen

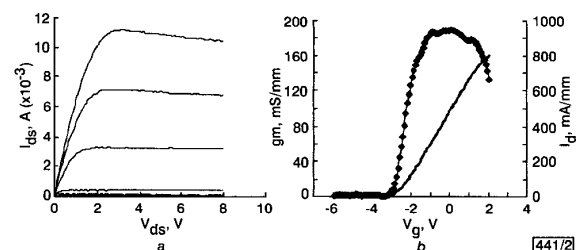


Fig. 2 Typical DC characteristics of FP GaN HFET

It is clear that a low contact resistance was achieved

Device structure and fabrication: The device was fabricated on an SiC substrate. Fig. 1 shows a schematic diagram of the fabricated FP GaN HFET. The source and drain ohmic contact metals (Ti/Al/Ta/Au) were first deposited and then annealed at 900°C for 30 s. A field plate was deposited on the surface of an Si₃N₄ passivation layer.